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Methods of Decreasing Absorption in Cement Mortars

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METHODS OF DECREASING ABSORPTION IN CEMENT MORTARS

BY

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THESIS

FOR THE DEGREE OF BACHELOR OF SCIENCE

IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1901

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OF Bachelor of Science in Civil Engineering

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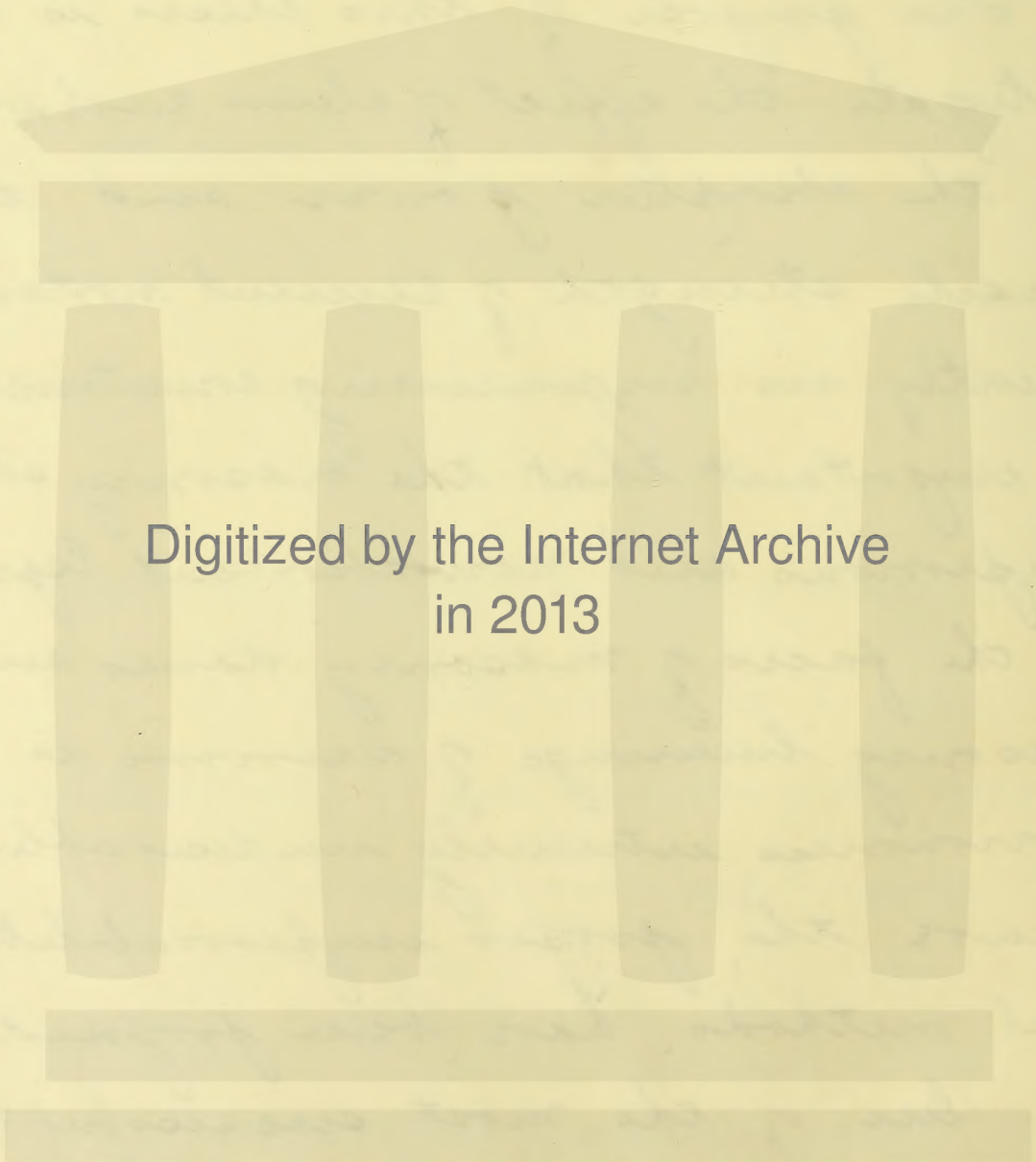
Introduction

The purpose of this thesis is to investigate the effect of alum and soap upon the absorption power and the tensile strength of cement mortars. Frequently in engineering construction it is important that the masonry shall be impervious and non-absorbent. Especially in the faces of masonry dams and the masonry linings of reservoirs is this pervious ness extremely undesirable. To secure the proper impervious ability several methods have been proposed.

One of the most successful methods of bringing about the desired result is by forming in the pores of the mortar compounds of alum and the fatty acids



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of soap There are two slightly different methods of accomplishing this: one by successive applications of alum and soap washes to the surface of the masonry, and the other by incorporating the alum and soap in the mass of the mortar.

No record can be found of the introductory use of alum and soap for this purpose, but they seem to have been first proposed by Sylvester, an Englishman, — at least these washes always bear his name. Doubtless they have been frequently used for this purpose, but no record of any such use could be found except in Baker's Masonry Construction, pages 178–180, which gives an account of the successful application of these washes

to the walls of a brick masonry reservoir in New York City in 1863.

The second method of using alum and soap seems to have been introduced by Dr. William M. McMurtrie, chemist of the United States Agriculture Department, at Washington, D. C., about 1880. This method was used under his direction in manufacturing an artificial stone called Advance Stone, used for the trimmings of the National Museum and the fronts of a few stores and dwellings in Washington. Professor Baker in his Masonry Construction calls the above artificial stone, McMurtrie stone.

The writer could find no recipes as to the proportions of the alum and

soap to be used except as stated in the volume referred to above. According to page 179 of Baker's Masonry Construction," Sylvester's method of decreasing permeability consists of the alternate application of two washes, - one composed of soap and water, and the other of alum and water. The proportions are three-quarters of a pound of soap to one gallon of water, and half a pound of alum to four gallons of water, both substances to be perfectly dissolved in the water before being used."

According to page 101 of that book, the recipe for making cement mortar impervious by incorporating alum and soap in it, is as follows: —

"one percent, by weight, of powdered

alum is added to the dry cement and sand and thoroughly mixed; and about one percent of any potash soap (ordinary soft soap made from wood ashes is very good) is dissolved in the water used in making the mortar."

The action of the alum and soap within the pores of the mortar seems not to have been carefully studied. Professor Baker in his Masonry Construction (page 101), in giving the second recipe above, italicizes the word potash, apparently implying that only potash soap can be used. It is known that practicing engineers have employed potash soap with success, and also that in some cases where soda soap

was used the mortar did not set at all. Dr. McMurtrie is quoted to the writer by good authority, as saying that a soda soap could not be used.

It is not clear from chemical equations that potash soap acts materially different from soda soap. The formula for a potash soap is $C_{16}H_{35}C.O.O.K$. The formula for a soda soap is exactly the same except that Na takes the place of K in the above formula. The formula for alum is $K\,Al(SO_4)_2$. The following equation shows the reactions and the resulting compounds when the alum solution is mixed with the potash soap solution.—

$$3C_{16}H_{35}COOK + K\,Al(SO_4)_2 = Al(C_{16}H_{35}COO)_3 + 2K_2SO_4.$$

The first compound is an insoluble glyceride, and the second a soluble potassium sulphate. By using a soda soap we have the following equation.—

$3C_{16}H_{35}COONa + K_2Al(SO_4)_2 = Al(C_{16}H_{35}COO)_3 + KNaSO_4 + Na_2SO_4.$

The first compound in this reaction is the same as the first one in the above equation. The second is a soluble potassium-sodium sulphate. The third is a soluble sodium sulphate.

From the above equations it appears that in each case the alum and soap combine and form compounds of alumina and the fatty acids which are insoluble in water. Also in each case soluble sulphates are found which do not

differ naturally in quantities and qualities. Since sodium and potassium have the same valence, it does not appear that the difference in result from using potash or soda soap in the above recipes should be very great. This phase of the matter will be referred to later.

It is proposed to investigate the efficiency of alum and soap in decreasing the permeability and absorption in cement mortars, and also the effect of these substances upon the tensile strength.

Effect upon Absorption.

The tests were made upon the form of briquette usually employed

in determining the tensile strength of cement. This form was adopted since it was a convenient specimen for these tests, and since the same specimen could be utilized in the tests to determine the effect of alum and soap upon the tensile strength. Experiments were made to determine the effect of the hydrostatic washes and also to determine the effect of incorporating alum and soap in the cement mortar.

Six series of experiments were made. The briquettes for each series were made at the same time by the writer with the same materials. In all cases the briquettes were made of neat Portland cement,— some-

times of Alpha, (American) and sometimes of Dyckerhoff (German). In reporting the results the kind of cement is always distinctly stated. In all experiments the briquettes were allowed to set twenty-four hours in the molds under a damp cloth.

In each case the absorption was determined for an immersion of seven days. After taking the briquettes from the water they were lightly wiped with a piece of blotting paper to remove all free water. The absorption is given in percents of the weight of the dry briquette.

The weighing was done upon the scales used for determining the fineness of cement. These scales were

selected as being abundantly accurate for the purpose, but unfortunately the unit is some unknown arbitrary quantity, — approximately 0.005 grams. However the exact unit is of no importance in this connection

The alum and soap washes were always applied hot, care being taken not to form a froth upon the surface. The soap solution was applied first, and each solution was allowed to dry twenty-four hours before the second was applied. The washes were kept at practically a constant density by the use of a hydrometer.

Three soaps were used: a Castile soap, a commercial soft soap, and a

home-made soft soap. Spectrum analysis of the first two soaps were made which showed that both had a sodium base. The home-made soft soap was made from wood ashes, and was therefore considered as having a potash base

Series 1.

This series of experiments was made to determine the effect of Sylvester's washes and also the effect of incorporating alum and soap. The cement used was Alpha Portland. Five experiments were made each consisting of six briquettes. After being removed from the molds, all the set six days in water and seven days in air. They were treated as shown

in Table 1, then weighed and immersed in water for seven days.

Table 1

Effect of Soda Soap.

Experiment Number	Method of Treatment.	Kind of Soap	Weight of six Briquettes		Absorption o/o
			Dry	Wet	
1	Untreated	. . . . .	142.1	149.4	5.2
2	Two coats of Sylvester's washes.	†Soda	3095	3286	8.4
3	" " " " " .	‡ "	3140	3257	5.8
4	1¼% alumand 2% soap incorporated	‡ "	132.3	142.6	7.7
5	" " " " " "	† "	134.9	143.1	6.0

According to Table 1 the untreated briquettes absorbed less than either those coated with Sylvesters washes or those having alum and soap incorporated. This anomalous result is unaccount-

† Castile Soap

‡ Commercial Soft Soap.

able. The only reason which can be offered is that allowing the briquettes to set in water does not permit of the proper action of the alum and soap with in the pores of the cement. There is no good proof of this explanation, but this view is upheld to a certain extent by the results given in Table R, page 15.

Series R.

This series was the same as the preceding except that the briquettes received four coats of Sylvester's washes and the incorporated alum and soap was increased from 1¼ percent to 2 percent, the soap remaining the same. Alpha Portland cement was used.

Table 2

Effect of Soda Soaps upon Absorption

Experiment Number	Method of Treatment	Kind of Soap	Mean Weight of Six Briquettes		Absorption %
			Dry	Wet	
1	Untreated	.....	3271	3365	2.9
2	Four coats of Sylrester's washes	‡Soda	3180	3260	2.4
3	" " " " "	† "	3207	3278	2.2
4	2% alum and 2% soap incorporated	† "	2918	2989	2.4
5	" " " " " "	‡ "	2925	3013	3.0

† Castile Soap ‡ Commercial soft soap.

According to Table 2 the treated briquettes absorbed slightly less water than those untreated. The small difference between the treated briquettes bears out the statement made with reference to Table 1, that the alum and soap do not

act to prevent absorption when the briquettes were allowed to set in water. No reason can be assigned why the results in Table 2 are only one-half to one-third as much as those in Table 1.

Series 3.

This series was made to determine the difference in effect between soda and potash soaps. The cement used was alpha Portland. Four experiments were made each consisting of six briquettes. After being removed from the molds the briquettes set six days in air. They were treated as shown in Table 3, then weighed and immersed in water for seven days.

Table 3.

Difference in Effect between Potash and Soda Soaps.

Experiment Number	Method of Treatment.	Kind of Soap	Mean Weight of Six Briquettes		Absorption %
			Dry	Wet	
1	Untreated.	.....	3124	3346	8.2
2	Three coats of Sylvester's washes	Potash§	3029	3154	4.0
3	" " " " "	Soda‡	3060	3155	3.1
4	2% alum and 2% soap incorporated.	Soda†	2841	2986	5.2
5	" " " " " "	Potash	2856	3021	5.5

† Castile Soap. ‡ Commercial Soft Soap. § Home-made Soft-Soap.

Table 3 seems to show that alum and soap decrease the absorption in cement mortars. It is evident from the above results that there is not much difference between soda and potash soaps in decreasing absorption. The soda soaps give the

least absorption There is a gain in the use of the washes over incorporating alum and soap. However this may be due to the fact that the washes more nearly place the alum and soap where they are most needed than is afforded by the even distribution throughout the mass which occurs when they are incorporated. There was no method of determining the amount of alum and soap left in the form of the cement when they were applied in the form of washes.

Series 4.

This series was the same as Series 3, except that two kinds of soda soap were employed

Table 4.

Difference in Effect between Potash and Soda Soaps.

Experiment Number	Method of Treatment	Kind of Soap	Mean Weight of Five Briquettes		Absorption %
			Dry	Wet	
1	Untreated	.....	3117	3372	8.1
2	Three coats of Sylvester's Washes.	§Potash	3114	3282	5.3
3	" " " " " .	†Soda	3128	3252	3.9
4	" " " " " .	‡Soda	3090	3196	3.4
5	2% alum and 2% soap incorporated.	§Potash	3021	3163	4.7
6	" " " " " .	‡Soda	2986	3103	3.9

‡ Castile Soap. † Commercial Soft Soap. § Home-made Soft Soap.

The results of Table 4 are very similar to those of Table 3. They tend to establish the following facts, first that soda soap decreases absorption more than potash soap, and second that Sylvester's washes decrease the ab-

sorption more than the incorporated alum and soap.

Series 5.

This series was made to determine the effect of a different number of coats of Sylvestris wash. The cement used was Dyckerhoff German Portland. Six experiments were made each upon five briquettes. After being removed from the molds the briquettes set six days in air. They were treated as shown in Table 5, then weighed, and immersed in water for seven days. In this series only Sylvestris washes were used, no briquettes being made with incorporated alum and soap.

Table 5

Effect of Sylvesters Washes.

Experiment Number	Method of Treatment	Kind of Soap	Mean Weight of Five Briquettes		Absorption %
			Dry	Wet	
1	Untreated	.....	3045	3219	5.9
2	Three coats of Sylvester's washes.	Potash	2936	3227	9.9
3	Four " " " " .	Potash	2882	3151	9.5
4	Three " " " " .	‡ Soda	2920	3205	9.75
5	Four " " " " .	† Soda	2915	3199	9.73
6	Untreated.	.....	2897	3263	9.2

‡ Commercial Soft Soap.
† Castile Soap

Not much information can be obtained from the results in Table 5. The difference in absorption in experiment and experiment 6 is due to the fact that the briquettes of experiment 6 dried eight days longer

than those of experiment. It is not known why there could be no material difference between the results of experiments 2, 3, 4, 5, and 6. This series was made with Dyckhoff cement while all the preceding have been alpha.

Series 6

This series was substantially the same as Series 5 except that the alum and soap were incorporated instead of being applied as washes. Dyckerhoff cement was used. Six experiments were made each upon five briquettes. After being removed from the molds the briquettes set six days in air, and were then weighed and immersed in water for seven days.

Table 6

Effect of Incorporating Alum and Soap.

Experiment Number	Method of Treatment	Kind of Soap	Mean Weight of Five Briquettes		Absorption %
			Dry	Wet	
1	2% alum and 2% soap incorporated.	Potash	2933	3151	7.43
2	4% " " 2% " " .	"	2790	3069	10.04
3	2% " " 2% " " .	†Soda.	2816	2990	6.17
4	4% " " 2% " " .	† "	2901	3088	6.46
5	Untreated.	.....	2859	3281	13.01
6	"	.....	2885	3253	12.75

†Castile Soap.

From the results of Table 6 it is very noticable that alum and soap, when incorporated, decrease the absorption. From Table 6, as also in Tables 3 and 4, it appears that soda soap permitted less absorption than

potash soaps. In both cases in Table 6, 2% + alum gave better results than 4%. The probable reason for this is that 2% alum was just sufficient to satisfy the soap and the other 2% dissolved out leaving oxide which filled with water.

Conclusion Concerning Absorption Tests.

The following conclusions seem to be justifiable.

1. There is no appreciable difference in the effect of soda and potash soaps. This is borne out both by the results of the experiments and by the chemical equations. No reason has been found to substantiate the statement that potash soap was the only soap which would

produce the desired effect. Both of these seem to be equally effective whether applied as washes or incorporated.

2. Sylvester's washes appear to be more effective than incorporating alum and soap. There was not enough variety in the proportions of alum and soap incorporated to show certainly whether this method was not as effective as that of Sylvester's washes. However, since the washes gave the best results, and also because they are applied so as to deposit the insoluble precipitate where it is most efficient, the writer believes that ordinarily the washes are preferable to the incorporation of alum and soap.

The above conclusion is based upon

the assumption that the expense is the same for both methods. In the only example on record, the cost of applying four successive coats of the washes was ten cents per square foot; but a large part of this was for heating the surface and therefore this is no criterion. In warm weather and under ordinary conditions, the expense would probably not be more than 8 or 10 cents per square yard. In incorporating the alum and soap with the mortar, it is only necessary to dissolve the soap in the water to be used in mixing the mortar, and to add the powdered alum to the cement and sand. In this case the chief item of expense is for the purchase of materials; but this

will not be very great, since the alum and soap need be added only to the mortar in the face of the joints, or to the pointing mortar, or to a plastering coat. Only a trial under the conditions of practice can show the exact cost of either process.

Effect of Alum and Soap upon the Tensile Strength.

The effect of alum and soap upon the tensile strength was determined by breaking the briquettes of the preceding series. The results are shown in Table 7, page 28. Series 1, 2, 3, and 4 were made of Alpha, and 5, 6a, and 6b of Dyckerhoff German Portland cement. For additional information in regard to the briquettes of any series refer-

ence may be made to the series bearing the corresponding in the preceding pages.

Table 7

Effect of Alum and Soap upon the Tensile Strength

Series No	No of Briquettes Broken	Age in Days	Kind of Cement	Untreated	Soda Soap		Potash Soap	
					Washes	Incorporated	Washes	Incorporated
6(a)	3	20	Dych.	471	....	254	....	251
2	6	26	Alpha	490	375	258	....	....
3	5	28	Alpha	478	379	459	370	430
Mean		25		479	377	324	370	340
6(b)	3	45	Dych.	559	....	534	....	505
4	5	50	Alpha	631	378	571	319	509
1	6	56	Alpha	637	618	417	....	....
5	5	63	Alpha	569	624	630	....	....
Mean		53		599	540	538	319	507

The results of Table 7 seem to show that the addition of soap and alum weakens the briquettes. For example, the mean of the untreated briquettes in the first three lines of the table, is 479 pounds, while the mean of the treated briquettes is only 363 pounds, or in other words, at about twenty-eight days the treated briquettes are only 74 % as strong as the untreated. The mean of the results in the last four lines is, for the untreated briquettes 599 pounds, and for the treated 476 pounds; that is, the treated briquettes are only about 80 % as strong as the untreated.

There seems to be no marked difference in the effect of soda and potash soaps. The results are too erratic to warrant any numerical comparison.

There seems to be but little differ-
ence between the effect of washes and
the incorporation of alum and soap.
The results here also are too erratic
to justify numerical comparisons.
It is somewhat astonishing that the
heated briquettes should be only about
three-fourths as strong as the untreat-
ed, and yet that there should be no
great difference between the alum
and soap when used as washes and
when incorporated in the mass. It
is not clear why the application of
the washes should materially decrease
the strength, while it seems reason-
able that the incorporation of alum
and soap might materially decrease
the tensile strength. Since appar-
ently the washes reduced the strength

as much as the incorporation of the ingredients, it is probable that either the difference in strength between the treated and untreated briquettes, or the similarity between the washed and the incorporated, is due to other differences in the experiments. However the results are too brief and erratic to certainly establish this conclusion.

Probably the time element is an important factor in determining the effect of using alum and soap. For example the mean of the soda soap at 25 days is 73% of the strength of the untreated specimens of the same age, while at 53 days it is 90%. This view derives some additional support from the fact that for 63 days

the treated specimens are stronger than the untreated

Suggestions for Further Tests.

For the benefit of anyone desiring to investigate this matter further the following suggestions may be helpful.—

1. The briquettes should be carefully and thoroughly dried, both before and after being washed. In all probability the failure to do so was a source of great error in the preceding experiments

2. It would be wise to test mortars of different proportions of sand and cement. All the preceding experiments were made with neat cem-

ent mortar

3. Possibly there may be a difference in the action of the soap and alum with different brands of cements,— both Natural and Portland. This should be investigated

4. It would be interesting to determine the effect of different numbers of coats of the washes; and also the effect of incorporating different quantities and different proportions of alum and soap.

5. With the alum and soap incorporated in the mortar, possibly there is a difference in effect whether the briquettes set in air or in water.

6. It would probably be wise to test the efficiency of these washes by applying them to a brick or perhaps

to bricks of different degrees of hardness.

7. It would be interesting to determine the relative effect of soda and potash soaps.

8. Since the preceding experiments seem to show that the use of alum and soap either as washes or incorporated in the mass decreases the strength one-fourth, it is important to make further and more elaborate tests on this subject.

9. Since there have been cases in practice in which the use of soda soap seems to have retarded the setting of the cement, it is desirable that further tests should be made as to the relative effects of potash and soda soaps upon the tensile

strength of cement mortar.